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Long-term correction

Uncertainty correlation methods and different long-term data

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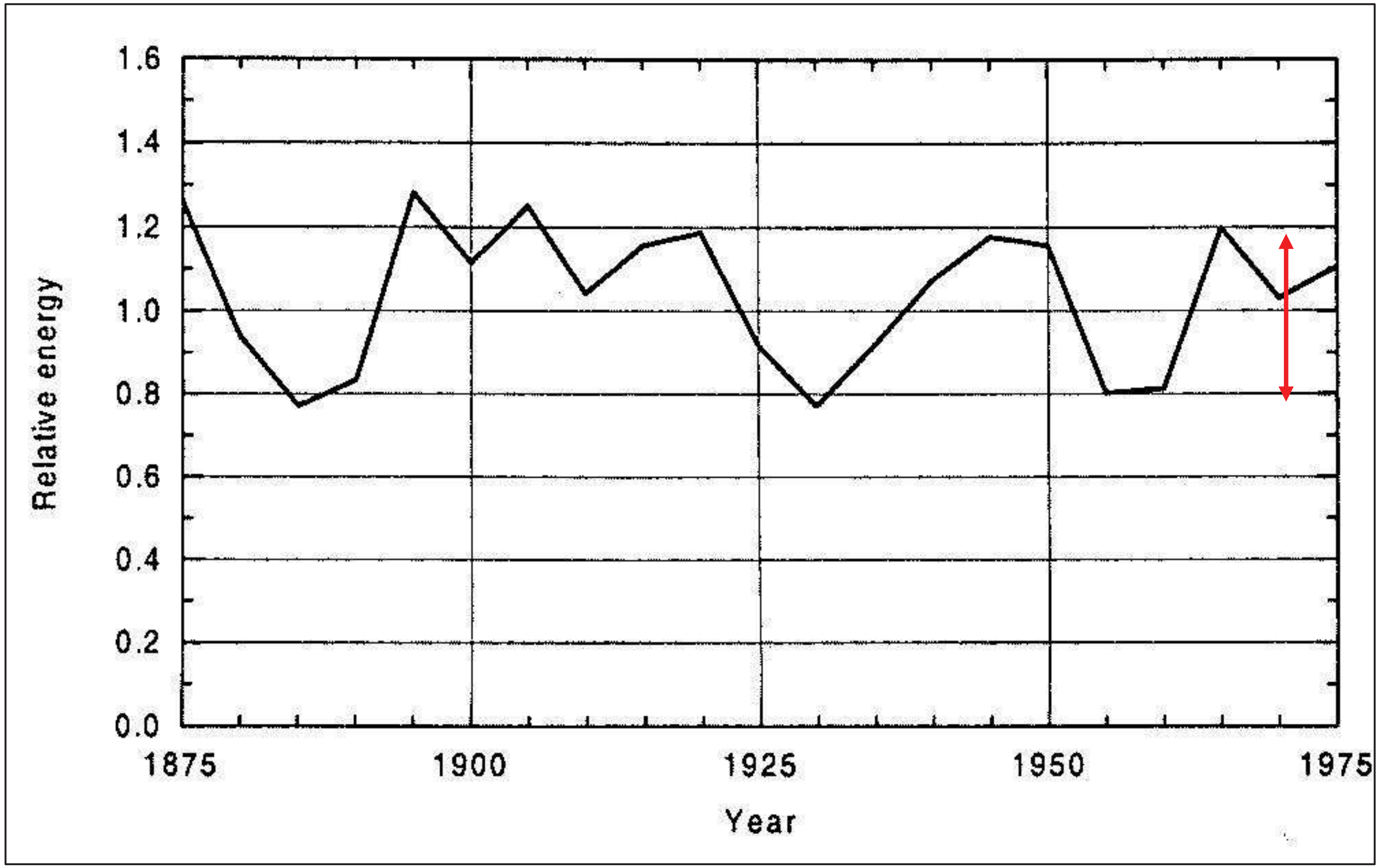
Long-term correction

- Motivation – why is it worth detailed analysis?
- LT and Site data sources
- MCP methods
- Statistical methods
- Serious number crunching
- Uncertainty model
- Results

Motivation: the meteorological reality



+/- 20% Energy Density

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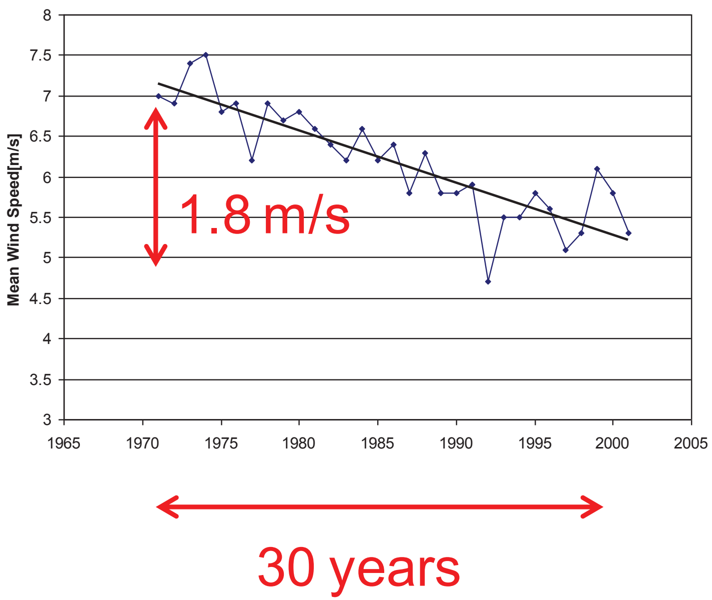
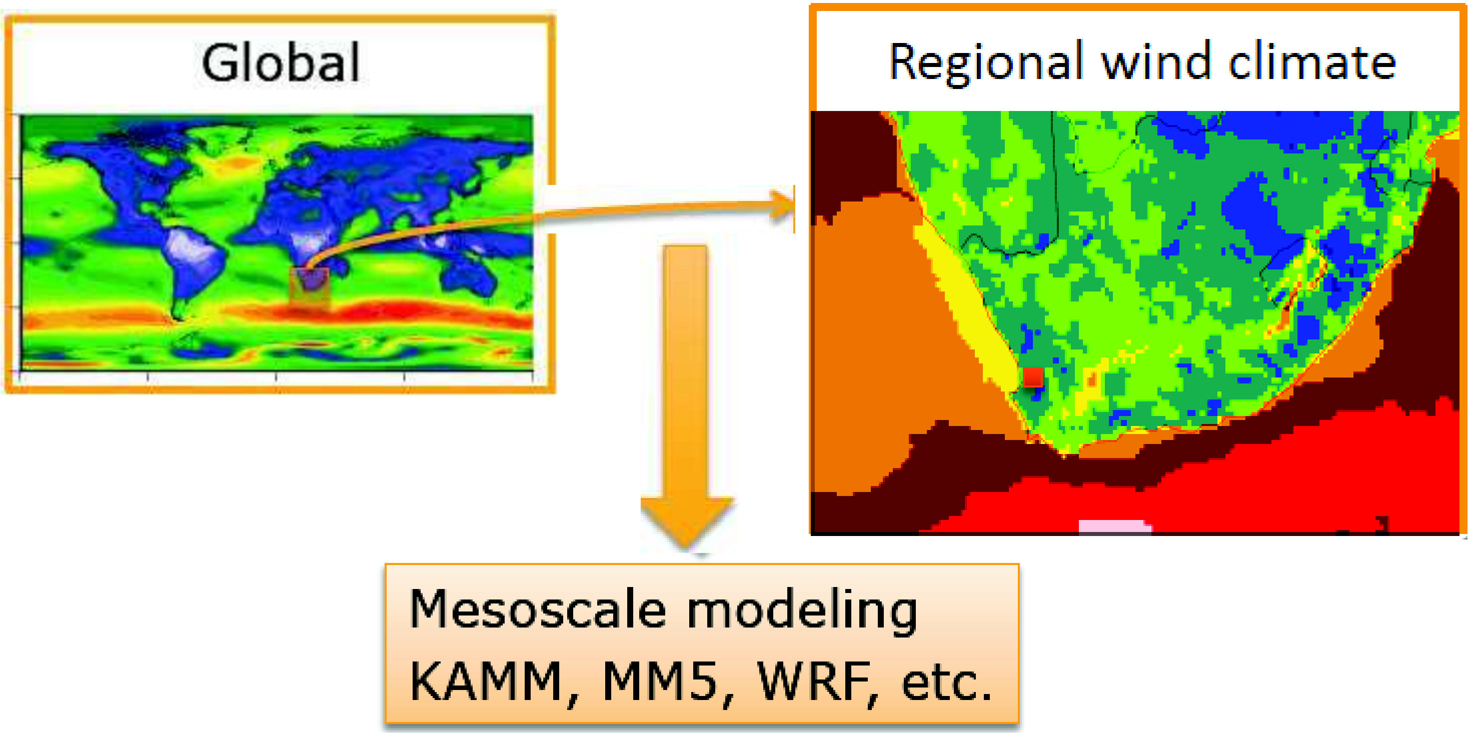
Quest for Quality LT data

1. Meteorological station
   - Vegetation
   - Building activity
   - Degrading instrumentation
   - …
2. Synthetic data – an alternative?
   - Temporal resolution
   - Spatial resolution



Re-analysis versus Meso-scale



Re-analysis data:
Assimilation of historical observational data using a single consistent assimilation (or "analysis") scheme

Meso-scale data

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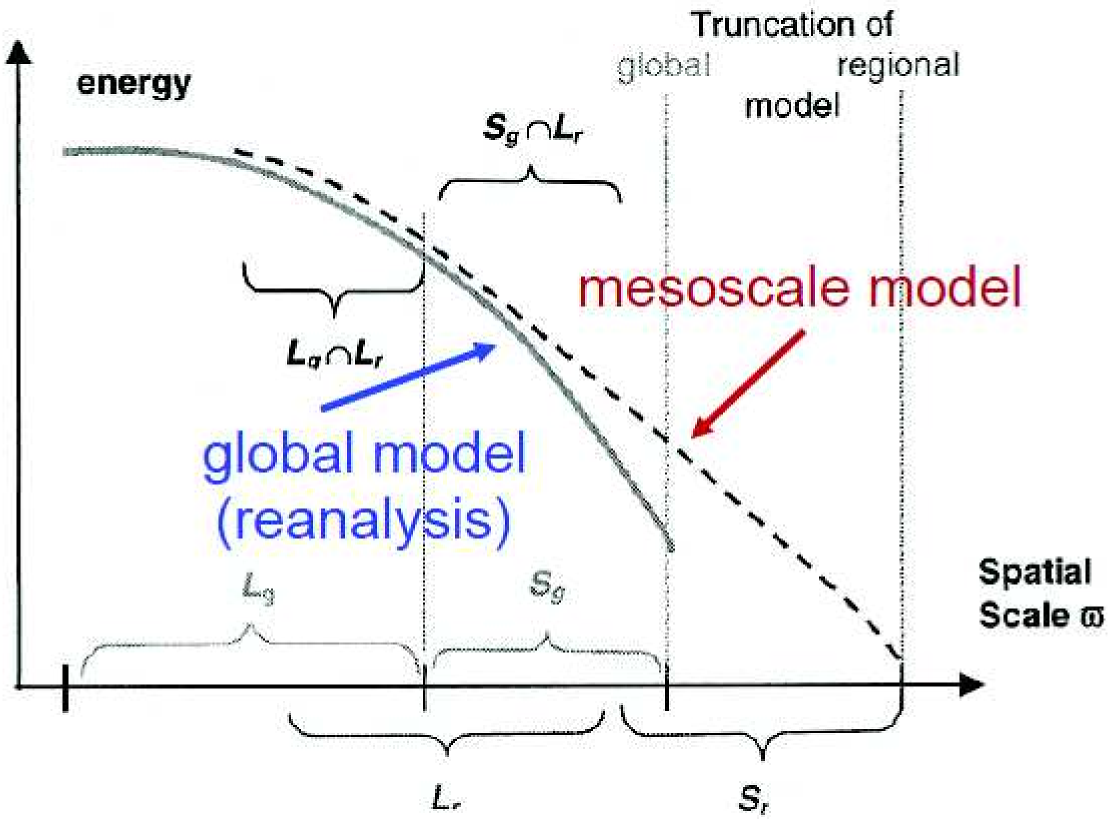
Re-analysis versus Meso-scale

- Meso-scale models resolve smaller scales not present in the reanalysis



von Storch et al (2000)

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Our Sites and their statistics

- High Quality masts accepted if
  - Pearson-Yearly-Wind Speed between Reanalysis-Mesoscale and Site is high and comparable
  - Monthly Pearson values between site and LT dataset are all above 0.8 at all years
  - 6 sites accepted, 2 sites rejected

Description	Recovery Rate	Measurement height	Measurement Years	Wind Speed Mast	Pearson yearly wind speed between datasets		
	%	m	#	Yearly m/s	Mesoscale-Reanalysis	Site-Reanalysis	Site-Mesoscale
Australia (Hilly)	92-100	50	8	9.45	0.96	0.94	0.94
Europe Complex	93-100	39	8	5.94	0.96	0.94	0.94
Brazil coastal	95-100	60	7	8.69	0.95	0.94	0.94
US catabatic	64-99*	80	9	4.59	0.68	0.71	0.69
Europe Nearly Offshore	89-100	70	18	8.27	0.92	0.84	0.78
Europe Flat	87-100	40	19	6.45	0.92	0.81	0.93

* All years with the exception of one >94%

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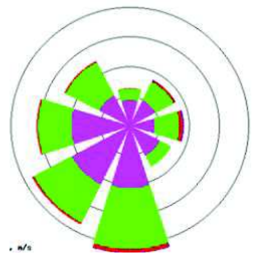
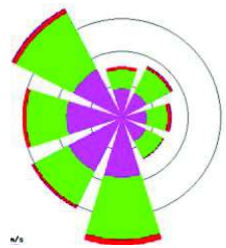
MCP Methods

1. Linear regression
   - Creation of artificial time series based on mathematicial link V_{ST} and concurrent V_{LT}
   - On-site wind rose is modified towards the LT wind rose





2. Wind index (energy index)
   - Converting wind speed into energy through application of a simplified power curve and comparing E_{LT} with E_{ST}

- More details: see WindPRO handbook

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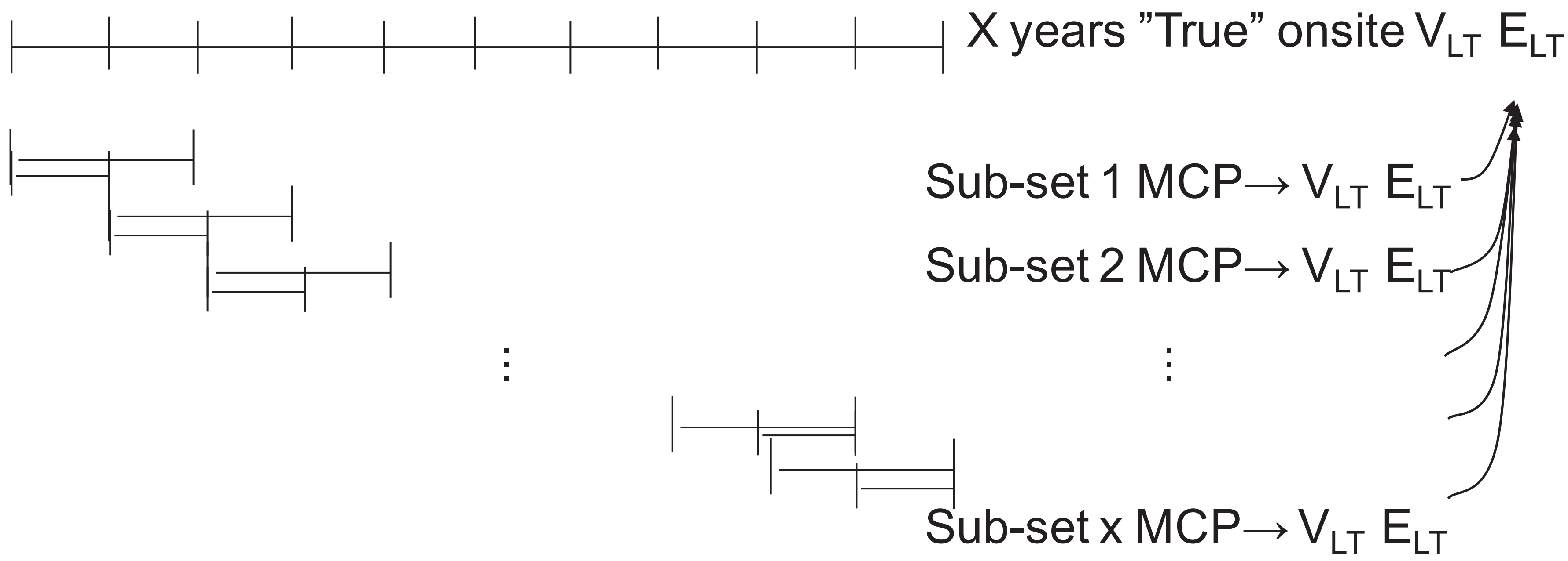
Back to our study

- High quality long-term onsite data
- Perform LT corrections with :
  - re-analysis (hourly)
  - meso-scale (hourly, 3km resolution)
- Use 2 different MCP methods (WindPRO default settings)
  - Linear Regression
  - Energy Index
- Use uncorrected site data- as benchmark
  - Site method

How?



X-1 subsets 6*(X-1) results per site (V_{LT} E_{LT}) for (Linear, Index, Site)

→ Bias, St. deviation of V_{LT} and E_{LT}

→ E_{LT} best at modelling uncertainty

Why Energy Density

- Using all sector energy density
  - Turned out more easy to model E_{LT} than V_{LT} uncertainties
  - More sensitive to high energy density sectors as ~ frequency * V^3

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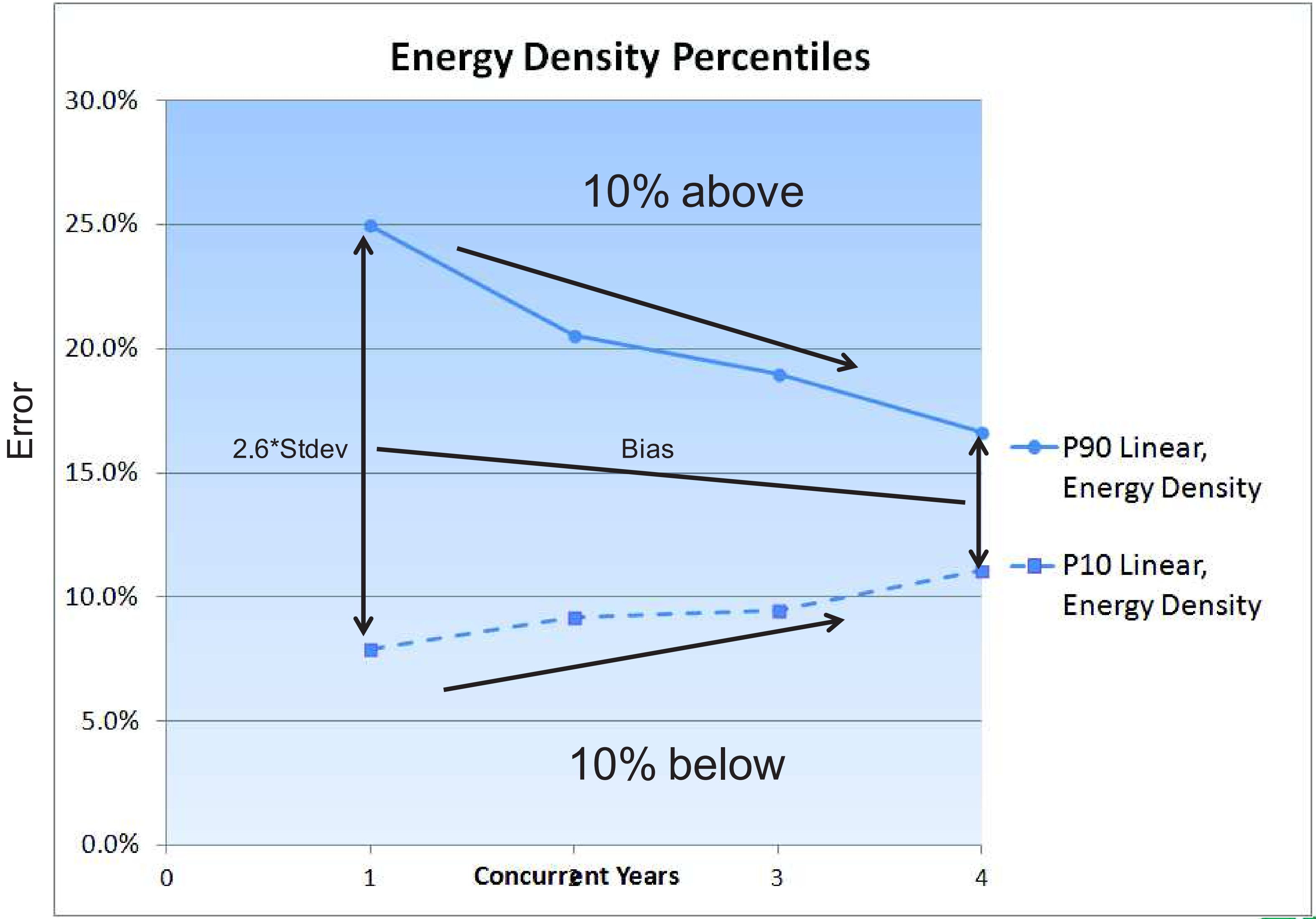
Why did it get so complicated?

- We have a bias (=offset) and a standard deviation (=uncertainty)
- Not able to predict and correct bias
- A method can have a very low standard deviation but a high bias or the other way round – which one is better?
- How to combine bias and standard deviation?
  - P90/P10 based on bias plus standard deviation (Site)
  - Absolute value of bias plus standard deviation (Model)

Site: Linear Method



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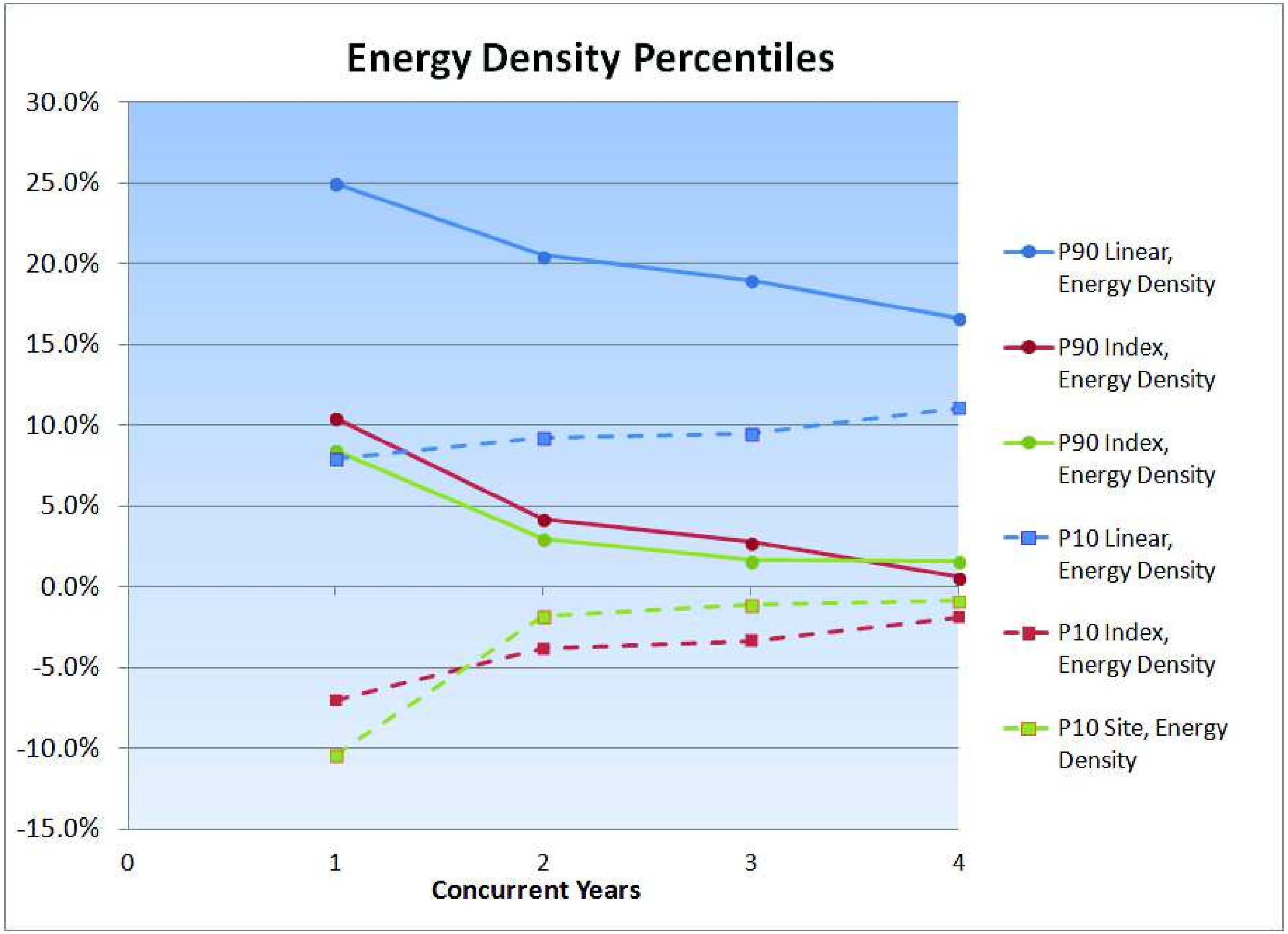
Site: Linear, Index, Site



Site Info
Pearson Monthly
0.88-0.95
Pearson Hourly
0.52-0.58
Variability
3.3%-3.9%

Linear regr: Biased not reducing error at this site
Index: Not Biased close to Site result
Site : Fast gain using several concurrent years

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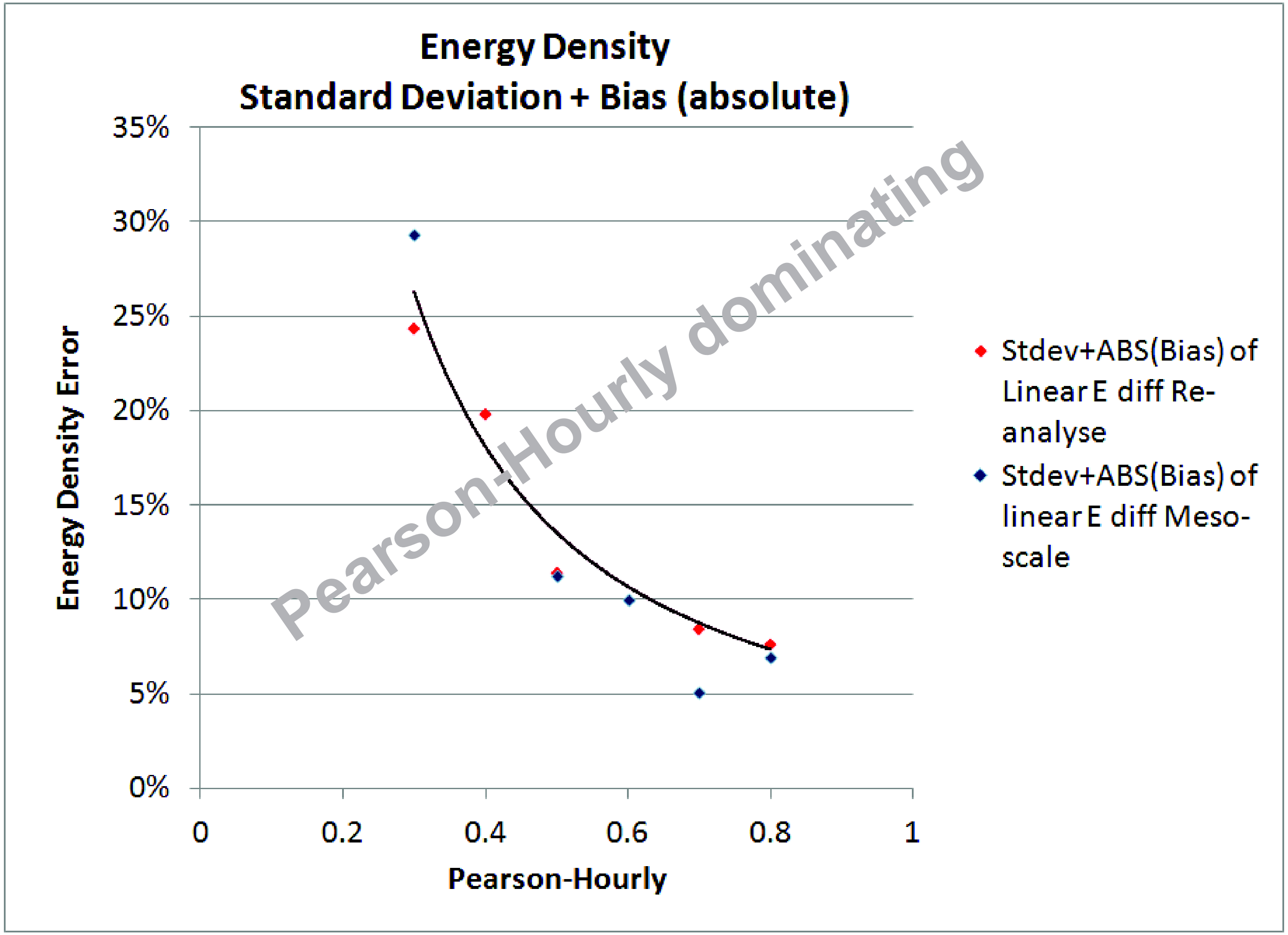
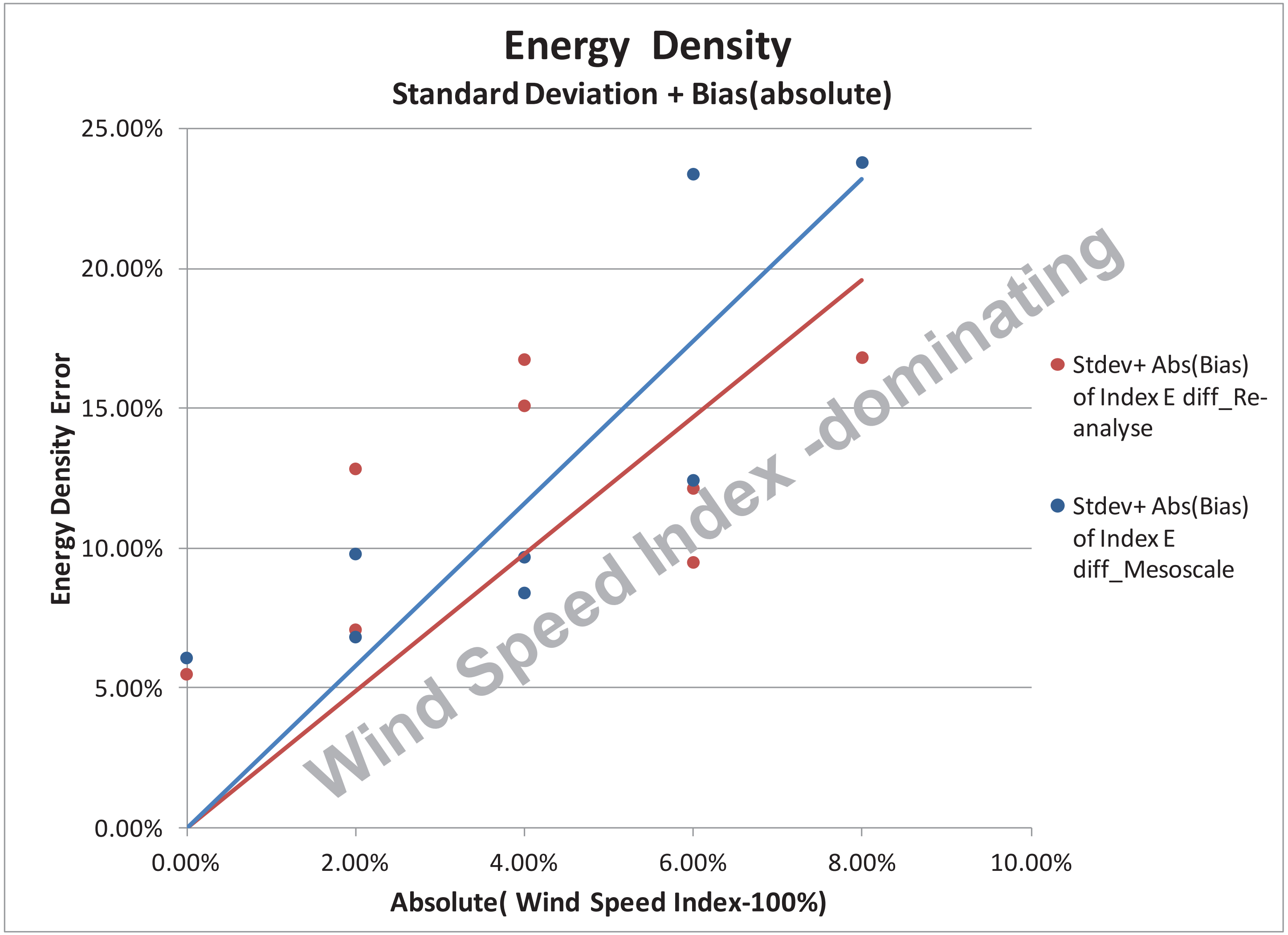
Site: Observations

- Index method best at 4 sites
- Site method best at 1 site
- Linear regression method best at 1 site with Pearson_Hourly >0.8
- Linear regression has high bias problems at Pearson_Hourly <0.6

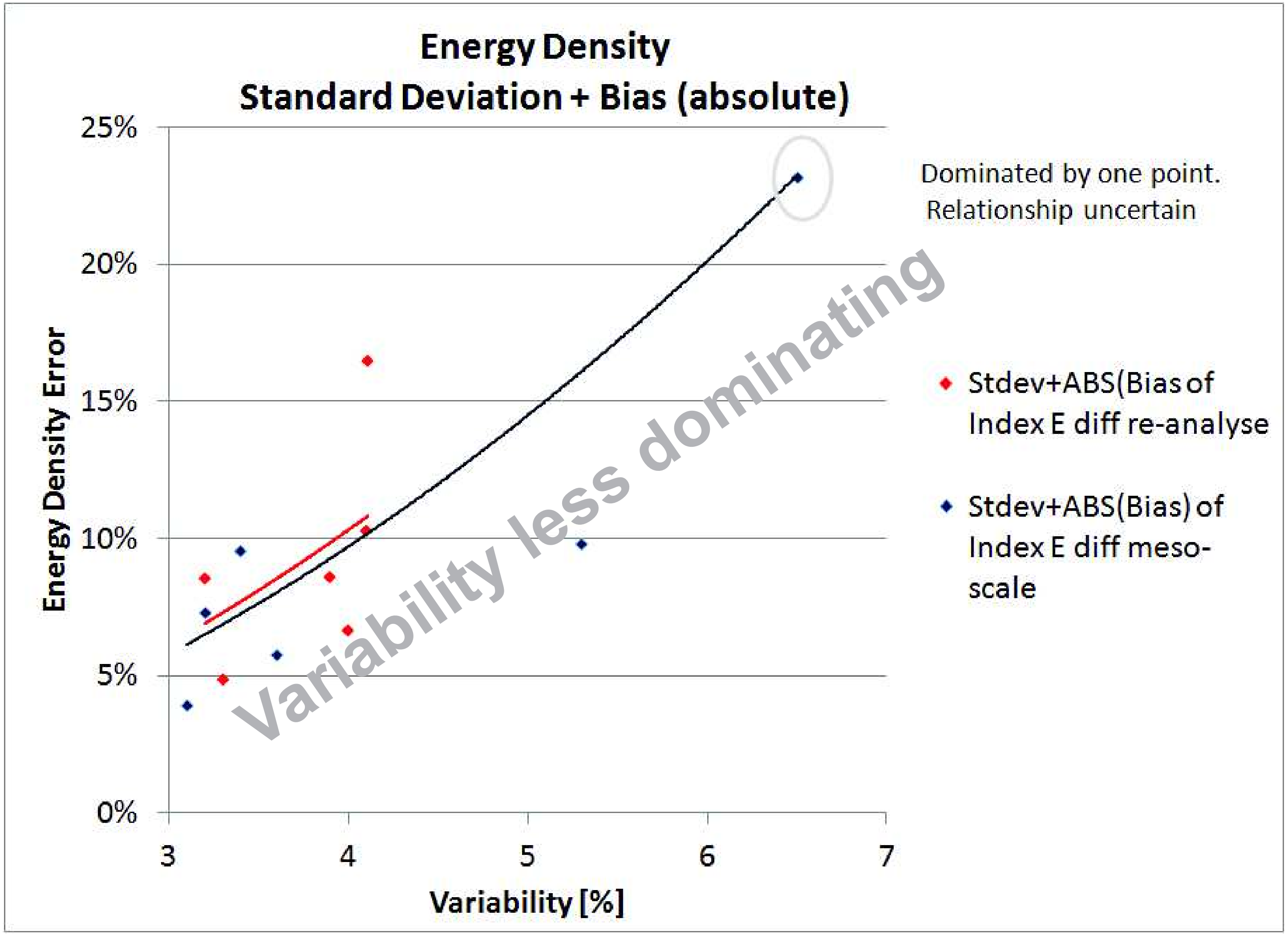
Model: Pearson-Linear Regression



Model: Speed Index-Index Method



Model, Variability-Index method



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Tying everything together

- Four drivers influence the error
  - Hourly Pearson R (the strongest driver)
  - Wind Speed Index
  - Number of concurrent years
  - Variability (the weakest one)
- Proposed scheme for combining them:

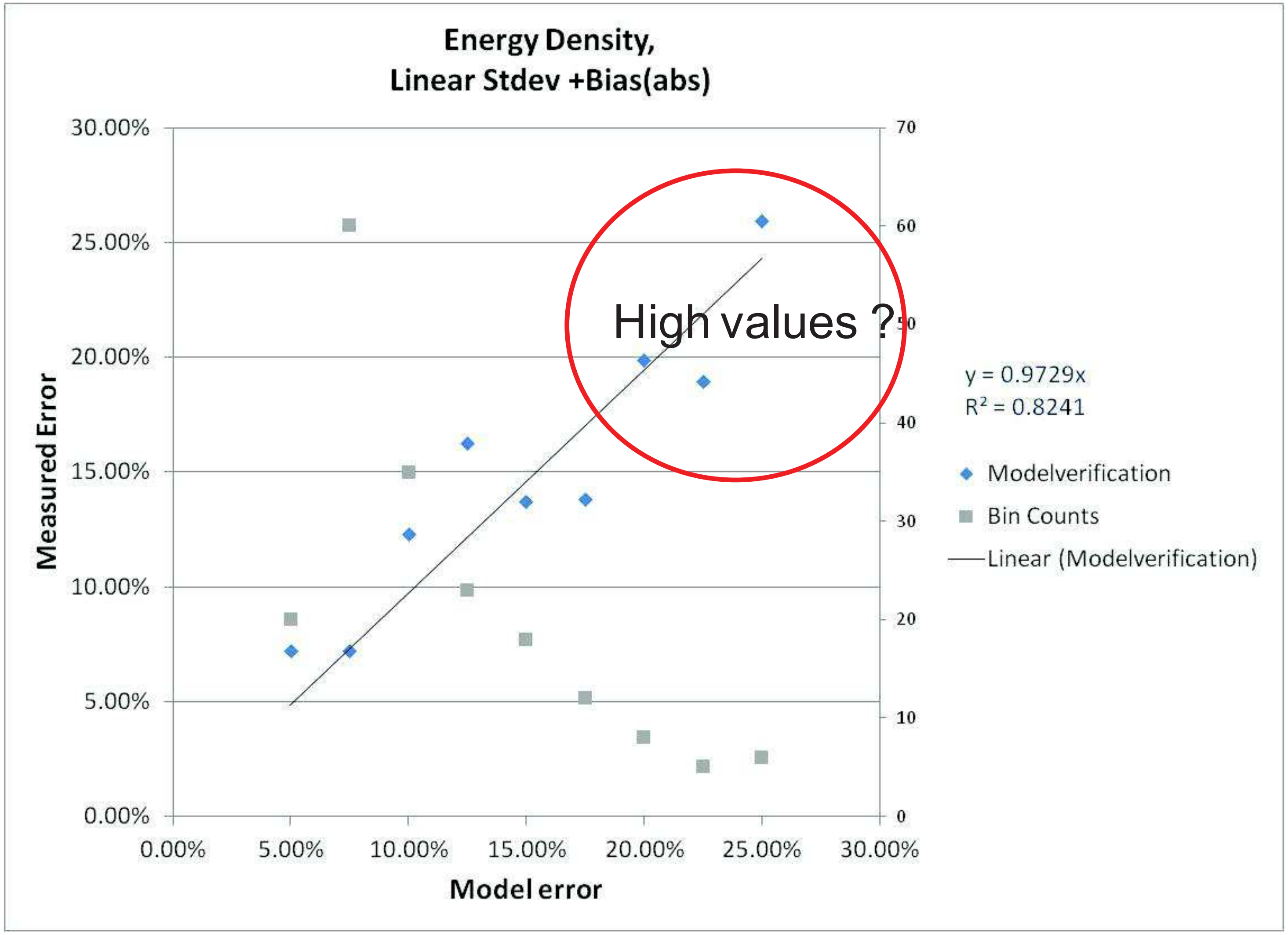
Model	
1	A*ABS(100%-Index Year)
2	B*(Pearson-Hourly)^{C}
3	D(Variability%)
4	(Concurrent Years)^{E}
Uncertainty	Combined = sqrt($1^2+2^2+3^2$)*4

Model parameters and results

- Index Method usual competitive
- Site Method competitive at low Wind Speed Index and/or several concurrent years
- Linear Correlation competitive at high Hourly-Pearson

Model	Parameter	Method		
		Linear	Index	Site
A*ABS(100%-Index Year)	A	1.55	1.55	3.7
B*(Pearson-Hourly)^C	B	0.06	0.05/0.07	
	C	-1.3	-0.9	
D(Variability%)	D	0.2	0.2	2
(Concurrent Years)^E	E	-0.3	-0.3	-0.5
Combined = $\text{sqrt}(1^2+2^2+3^2)*4$				
Pearson-Hourly > 0.3	**Reanalysis Data**		**Mesoscale Data**	

Model Example Re-analyse Linear



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Conversion: Energy Density-Production

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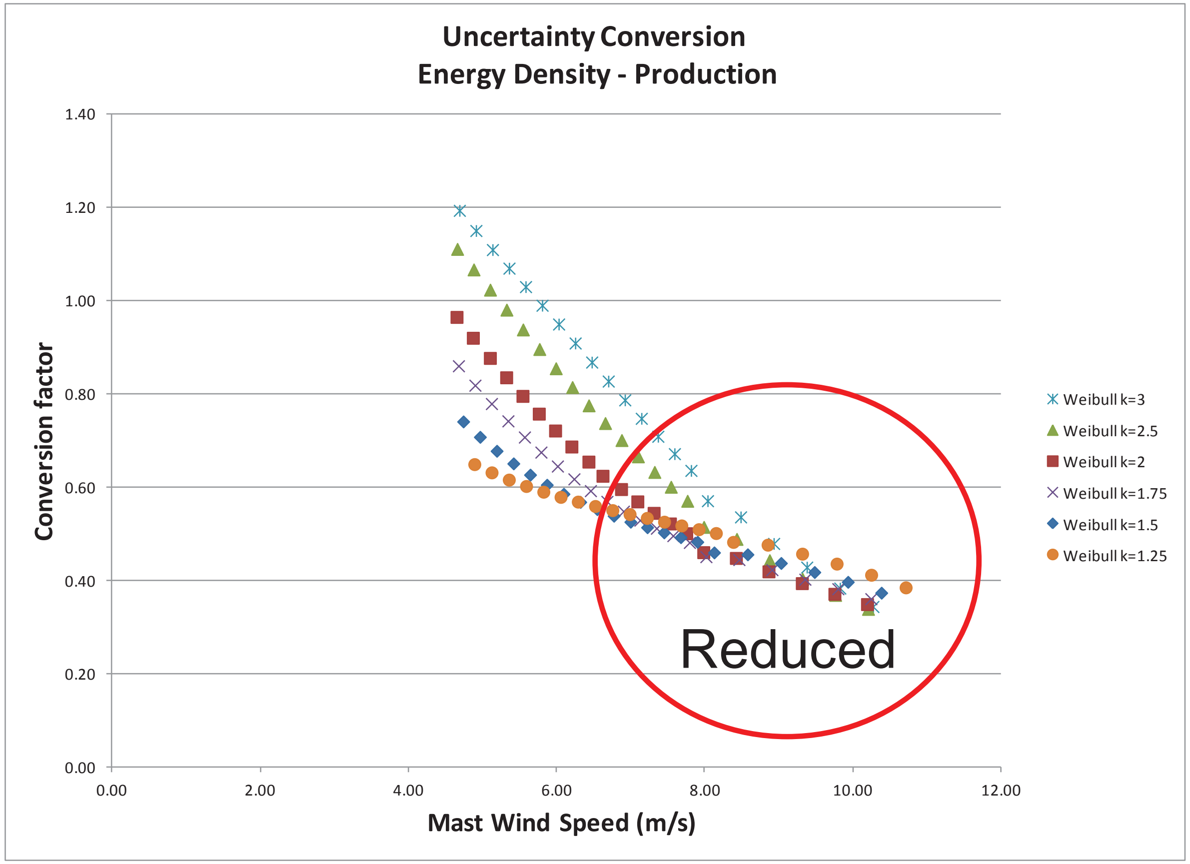
- $E = \rho * \text{no of hours} * v^3$ is compared with production per bin
- For each Weibull set one conversion factor



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Results

- LT correction does not always add value
- Energy Density seems to be a better indicator than wind speed
- Four main drivers identified for error
  - Hourly Pearson seems to be the decisive factor to decide method and type of data
  - Length of data set
  - Wind Speed Index
  - Variability is the weakest driver

Results (2)

- Proposed scheme to combine all four error sources and recommend correlation method
- Method developed to convert energy density to production
- All findings have been implemented in an automized Production uncertainty estimator
- Uncertainties above 10% on Production Estimates possible ☹.
- Linear correlation method is often biased at low Pearson values


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